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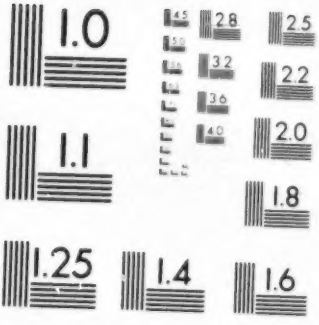

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ABSTRACT

This publication discusses the nature and consequences of acid precipitation (commonly called acid rain). Topic areas include: (1) the chemical nature of acid rain; (2) sources of acid rain; (3) geographic areas where acid rain is a problem; (4) effects of acid rain on lakes; (5) effect of acid rain on vegetation; (6) possible effects of acid rain on humans; (7) economic losses related to acid rain; and (8) a possible solution (suggesting that the pollutants causing acidity be controlled). Comments from the National Academy of Sciences on the acid rain problem, proposed federal legislation related to the growing environmental threat posed by acid rain, and information on what individuals can do to help control acid rain are included. (JN)

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ACID RAIN

What It Is—
...w You Can Help!

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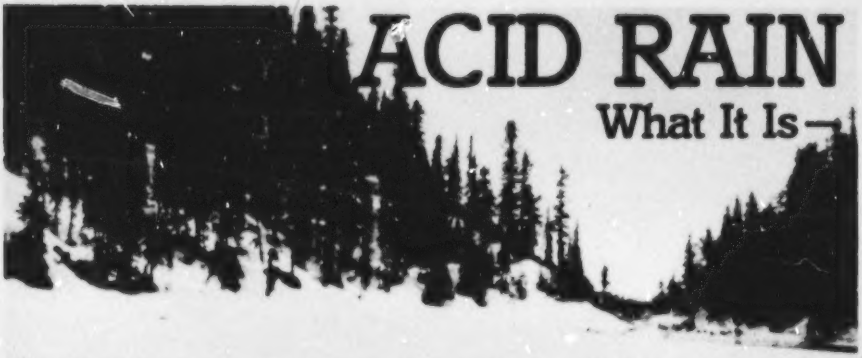
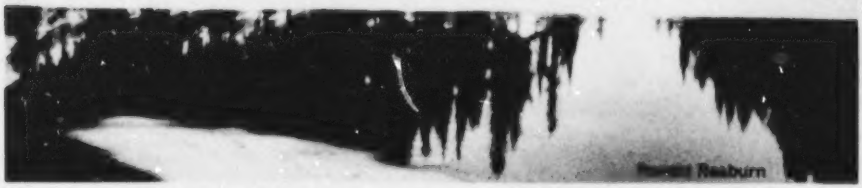
ACID RAIN

What It Is—





Bear, deer, fox, and beaver still roam the woods in the mountainous areas of New York's Adirondacks, the largest state park in the continental U.S. Raptorial birds still soar on the thermal updrafts. Sparkling blue lakes, once famous for fat native trout, dot the area. But something's wrong. The wood frog's chirp has been stilled. Stands of beech, spruce, and tamarack show signs of disease. And in more than 200 of the shimmering lakes, the trout are gone. Osprey, loon, and kingfisher no longer frequent these lakes. The otter, unable to find crayfish, has long since gone elsewhere.

Of all these foreboding signs, it is the disappearance of fish that has become the symbol of a growing environmental tragedy.

When the fish started dying in the 1920's, lodge owners and anglers suspected natural causes. They blamed declining fish counts on savage winter storms and beaver dams. Many decades later, Scandinavian research revealed that death and disease are carried to the Adirondack region in the winds. The culprit: a phenomenon technically known as acid precipitation. This insidious pollution falls to earth in such forms as rain, snow, ice, hail, and even fog. It is commonly called acid rain.

Acid rain's corrosive hand touches more than lake life. Forests and other vegetation are vulnerable to acid rain attack. It etches its devastation on certain vegetable crops, on painted surfaces of manmade objects, and on the metal or concrete facades of buildings. It may even affect human health.[1]

Acid rain has long been known in this part of the world. The effects of acid rain were first noted in the U.S. in the Adirondacks decades ago. Now we're finding acid rain in all parts of the country, from southern California to northern Maine; from Colorado to Florida. Acid rain is a growing threat to wildlife, crops, and human health.

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[1]Acid rain effects on forests and other crops, on man-made materials, and on human health are less well-documented than its well-established effects on lakes, streams, and aquatic life. Nevertheless, most knowledgeable scientists would agree that: forested areas are especially vulnerable to acid deposition; acid rain can alter long-term soil fertility with detrimental implications for long-term sustained agricultural and forest productivity; laboratory and simulation studies have documented leaf and foliar damage to trees and vegetables due to acidified water; acid rain-induced migration of heavy metals into the food chain is of great concern from the standpoint of human health and fish-eating birds and mammals; there is evidence that acid rain may liberate toxic metals in some ground waters and drinking water supply systems; and it is reasonable to assume that acid rain contributes to materials damage. See, e.g., U.S.-Canada Work Group 1 (under the Memorandum of Intent on Transboundary Air Pollution), Phase II Report on Impact Assessment, October 1981.

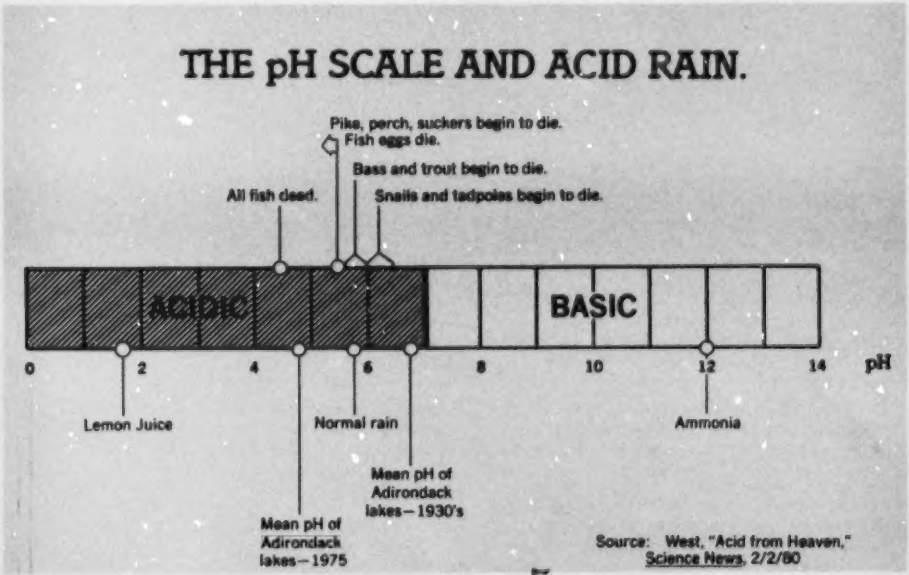
What Is Acid Rain?

Uncontaminated rain is slightly acidic (pH 5.6). But, because of air pollution, rain in most of this country is much more acidic than normal. The acidity of a liquid, soil or other substance is measured on a pH scale that ranges from 0—very acid to 14—very alkaline (or basic). A value of 7 is neutral. Distilled water is one of the few neutral substances. The pH scale is designed so every one-unit drop in pH represents a 10-fold increase in acidity. For example, pH 6 is 10 times more acid than a pH 7; pH 5 is 100 times more acid than pH 7. Precipitation having a pH less than 5.6—the theoretical pH of natural rainwater—is considered to be abnormally acidic. Rain in the Adirondacks averages about 4.2. The lowest reading ever was made in Wheeling, West Virginia, when a storm dropped rain measuring 1.5. By comparison, vinegar has a pH of 3.0.

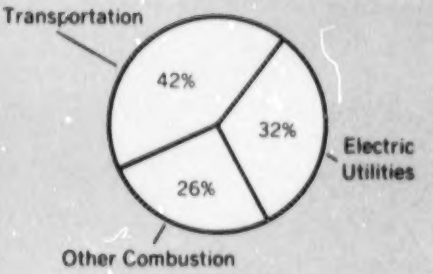
Where Does Acid Rain Come From?

Acid rain is formed from two kinds of pollutants, sulfur dioxide (SO_2) and nitrogen oxides (NO_x), which are emitted primarily from utility and smelter smokestacks, and from the tailpipes of cars and trucks. Sometimes these pollutants react with oxygen in the air, become heavy aerosols, and fall to earth in a dry form. More often, they are ejected high into the atmosphere—usually from tall smokestacks—hitch rides on prevailing winds and travel for days, moving hundreds or thousands of miles from their source. In the course of their journey, they combine with moisture in clouds and are converted to acids. The sulfur dioxide becomes a mild solution of sulfuric acid and the nitrogen oxides form nitric acid. These acids are cleansed from the air by rain, snow, and other forms of precipitation, and fall to the earth beneath.

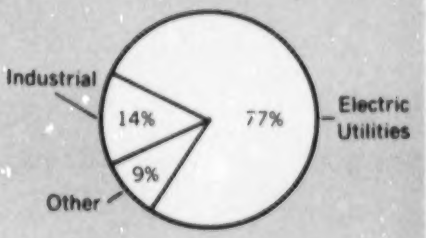
In the West, nitrogen oxides, streaming from utility stacks and the tailpipes of cars and trucks, combine with moisture to form nitric acid as the main component of acid precipitation. In the East, the big problem is sulfuric acid produced by sulfur dioxide emissions from the tall stacks of power plants. The biggest offenders are power plants in the Ohio River Valley, but emissions also come from other areas such as the Great Lakes industrial sector. The consensus among experts is that the burning of fossil fuels is the root of the acid rain problem.



Sources of No_x and SO_2 Precursors to Acid Rain.



Nitrogen Emissions
Totaled 24.5 million tons/yr.



Sulfur Dioxide Emissions
Totaled 25.2 million tons/yr.

Note: 1978 Data
Source: Modified from National Commission on Air Quality, 1981.

Where Is Acid Rain A Problem?

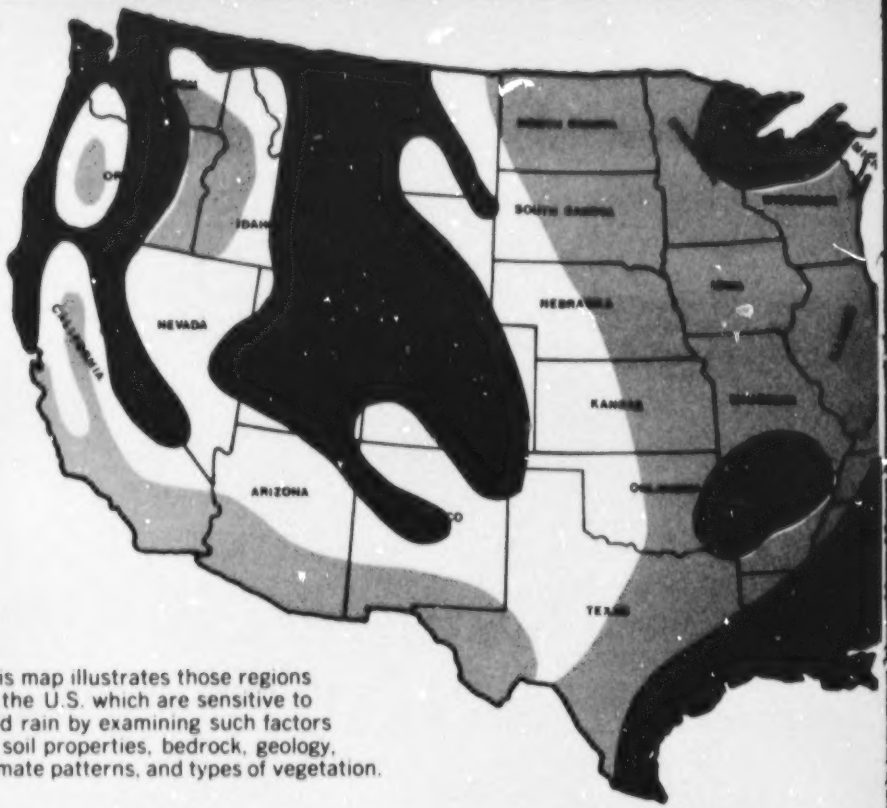
Thirty-one states in the Eastern U.S. and several provinces in southeastern Canada are drenched with precipitation that averages 20 to 30 times more acid than normal rain. A National Wildlife Federation study found 15 of these states to be "extremely vulnerable" —both in terms of environmental impacts and building materials damage—to this acidic downpour.

About 70% of the sulfuric acid reaching the Adirondacks originates outside the mid-Atlantic area. Scientists using satellites have tracked the drift of polluted air masses from oil and coal burning power plants in the Ohio River Valley to the Adirondacks and to southeastern Canada, especially the provinces of Ontario and Nova Scotia.

The Adirondacks also absorb some acid rain formed from pollutants originating in areas like Sudbury, Ontario. These emissions come from tall smokestacks built by utilities and smelters over the past 20 years to alleviate local air pollution problems. These stacks, some more than 2000 feet tall, do help clear the air locally. But Newton's law still applies: what goes up must—and does—come down, somewhere.

By a cruel quirk of fate, many of the acids formed by sulfur dioxide and nitrogen oxides come down in places poorly equipped, geologically, to cope with them. In some areas, the soil can neutralize some of the acids in the rain. But soils like those in the Adirondacks are too thin and too low in alkaline components to neutralize or counter the effects of deposited acids. In these situations, the precipitation that runs off the land into mountain lakes can be highly acidic. The receiving lakes also lack the ability to buffer the acids. Thus unchecked, the acids act inexorably to alter the chemistry of the waters.

Upstate New York is not the only vulnerable area to receive acid precipitation.



This map illustrates those regions of the U.S. which are sensitive to acid rain by examining such factors as soil properties, bedrock, geology, climate patterns, and types of vegetation.

From Maine to California

Acid rainfall has been reported from all over the country. The sensitive Boundary Waters Wilderness Area of Minnesota is receiving an acid onslaught. Isolated spots in Washington and British Columbia are measuring precipitation at pH levels below 5.6. Rainfall in portions of the Southwest and central Colorado periodically reaches acidity levels 20 to 40 times that of "pure" rain. Areas of southern California are not exempt from an acid rainbath. Recently, Los Angeles recorded acid fog at pH 3. Vinegar!

It has been estimated that acid rain may be slowly poisoning 100,000 miles of streams and 20,000 lakes. These impacts have been most pronounced in the eastern half of the country.

- **At least 180 former brook trout ponds in the Adirondacks will no longer support trout because of acidification.**
- **At least 212 Adirondack lakes are fishless.**
- **Half the lakes in the Boundary Water Canoe Area Wilderness in Minnesota are vulnerable to acidification.**
- **More than 10,000 lakes in Michigan are susceptible to acidification; more than half of the 8,000 lakes and ponds in the western half of the upper peninsula are potentially susceptible to acid inputs.**
- **Wisconsin has over 2,600 vulnerable lakes.**
- **In Maine, 1,368 lakes have experienced an eight-fold increase in summer acidity from the 1920's to the 1970's.**

High Sensitivity

Moderate Sensitivity

Low Sensitivity

Source: B. L. Niemann, J. Root, N. V. Zwalenburg, A. L. Mahan, An Integrated Monitoring Network for Acid Deposition: A Proposed Strategy, November, 1979.

- Headwater streams in the New Jersey Pine Barrens have experienced a 17-year, statistically significant trend toward acidification.
- Thirty-eight streams in western North Carolina showed a decrease in pH and alkalinity in 80 percent of the streams surveyed between the early 1960's and 1979.
- Nine out of eleven lakes sampled in northern Florida were acidified.
- Overall, 38 to 81 percent (depending on the precise area examined) of the lakes and streams tested in the eastern U.S., and 13 to 48 percent of midwestern lakes, fall in the categories of "moderately sensitive to acid rain" to "already acidified."

More recently, the problem of acid rain has been recorded in the western U.S., long-regarded as relatively immune to acid rain and its effects.

- Rainfall in Boulder, Colorado, has become six times more acidic over a 3-year period.
- In Yellowstone National Park the rain is two and a half times more acidic than normal.
- In Montana's Glacier National Park, rain is falling with pH levels as low as 4.4.
- Rain 30 times more acid than normal was recently recorded at a monitoring station in Oregon.
- Precipitation with a pH of 3 has been collected in New Mexico's Sante Fe National Forest.
- In California, rainfall pH values as low as 2.9 were reported in 1978.

And the list of incidences of acid rain continues to grow.

Acid Rain Is Killing Lakes

Acid rain packs a powerful wallop, leaving few parts of an ecosystem untouched. Its destructive effects are best documented for aquatic systems like lakes and rivers and the life found in them. Lakes and rivers underlain with granite, rather than neutralizing limestone, are the least able to offer resistance to repeated acid drenchings. Acid precipitation can lower the pH of these waters, and also leach aluminum and other toxic metals from soils and bottom sediments.

The double punch combination of high acidity (low pH) and high levels of aluminum is deadly to fish and other aquatic life. It is so deadly that more than 200 lakes and ponds in the Adirondacks, and 140 lakes in Ontario are fishless. Some 2,600 lakes in Minnesota are in jeopardy of experiencing the same fate, their waters bordering on the fish-critical pH of 5.5. The National Academy of Sciences has projected that the number of acidified lakes in the U.S. will more than double by 1990, unless pollutants which cause acid rain are significanty reduced.

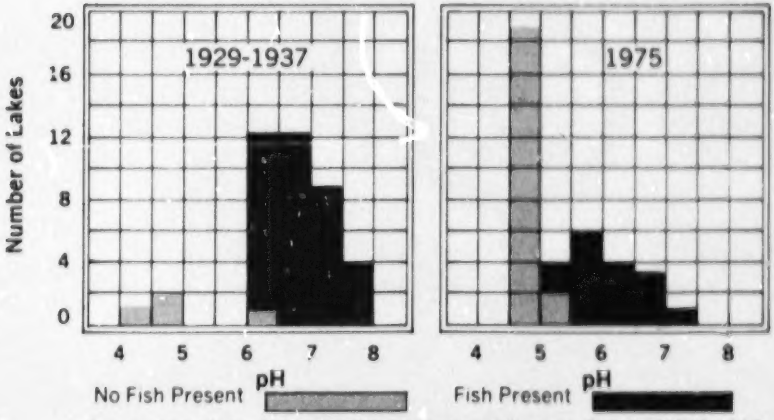
Because of the closely woven web of life, death has a domino effect. In an aquatic system that is altered by acid rain, fish are usually among the last organisms to suffer the destructive effects of the acid. Unfortunately, by the time the fish are gone, a whole freshwater community may have been altered irreversibly.

A healthy freshwater lake has a pH around 8; slightly alkaline. But continued input of acid rain, plus the sudden influx of acid from melting snow each spring, gradually deplete the lake of its natural agents that tend to neutralize the acid. The pH begins to fall.

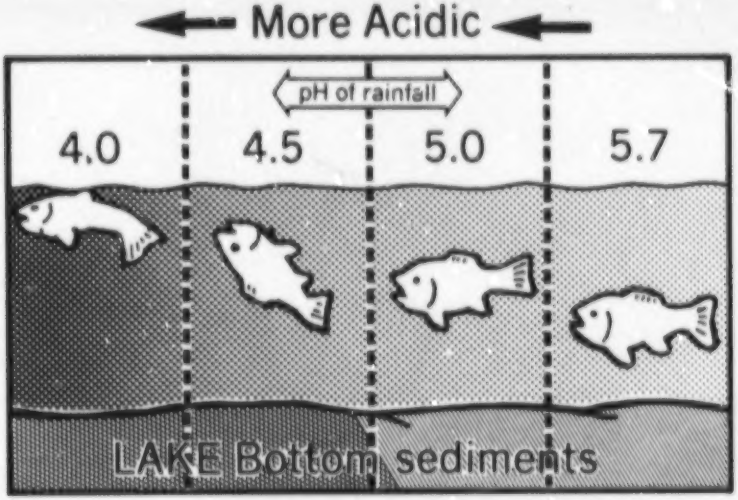
At pH 6.0 no freshwater shrimp can be found. As the pH falls to 5.5, bottom-dwelling bacterial decomposers begin to die. Leaf litter and other organic debris begin to collect on the lake bottom, and plankton—the base of the foodchain—starts to disappear. Toxic metals, such as aluminum, mercury and lead, are released from lake bottom sediments or leached from surrounding soils. Aluminum, which can damage fish gills, and the lowered pH can mean the beginning of the end for many fish. By the time the pH has fallen to 4.5, all fish, most of the frogs, and many of the insects have died. The lake may still be clear and blue, but the vibrant community of living organisms it once contained is now just a memory.

FREQUENCY DISTRIBUTION OF pH AND FISH POPULATION STATUS IN FORTY ADIRONDACK LAKES GREATER THAN 610 METERS ELEVATION

Surveyed during the period 1929-1937 and again in 1975.



Source: Schofield, C. L., "Acid Precipitation Effects on Fish," AMBIO 1976.



In addition to lowering the pH of freshwater lakes and rivers, acid rain can leach aluminum and other toxic metals from soils and bottom sediments.

Acid Rain Affects Vegetation

Acid rain is also harmful to vegetation. Though the detrimental effects are not completely understood, this much is known: from above, foliage is attacked; from below, roots are starved and sometimes poisoned. The aerial assault damages the protective waxy surfaces of leaves, allowing acidic poisons to diffuse into the leaves. Transpiration and gas exchange are interrupted; the plant can no longer "breathe." As a consequence, photosynthesis and seed germination are inhibited. An overall result: plant productivity and crop yields can decrease.

The few field studies of the effects of acid rain on vegetation that have been conducted reveal these facts: Bush beans, radishes and soybeans may be damaged. Yields of beets, carrots and broccoli may be reduced. Soft fruits, including tomatoes, may be spoiled, and apples may be spotted. While yields of spinach and lettuce appear to be unaffected by acid rain, the foliage of these vegetables can be so damaged that they are unmarketable. We are just beginning to estimate damages to crops. According to Dr. Thomas D. Crocker of the University of Wyoming, "Acid rain has already reduced the nation's agricultural revenue by $1 billion (1978 estimate), while its total economic effect in the eastern third of the U.S. may be as much as $5 billion."

In forested areas, spruce, pine, aspen, and birch trees are among the species most stressed by acid rain. Here again acid rain packs a double punch. Leaves, with their protective layer damaged, become more vulnerable to drought and disease. Weakened root systems, poisoned by the uptake of toxic aluminum leached from soils, and the injured leaves cause the tree to slowly begin dying. Die-back starts with reduced foliage and eventually leads to the death of the tree.

Acid rain also affects important soil-dwelling organisms. Certain bacteria, which have the capacity to enrich the soil by forming nitrogen, are killed by the increasing soil acidity. Other microorganisms that thrive on organic litter and humus are also killed by high acidity. As a result, the soil is robbed of sources of materials important to continued plant growth.[1]

As was noted in an earlier footnote, there is some controversy regarding acid rain effects on soils and vegetation. However, the impacts described in the text are based on laboratory and limited field evidence, and represent reasonable extrapolations from what is currently known or suspected by leading scientific authorities.

Acid Rain: A Threat to People

Humans, too, may not be immune to the effects of acid rain. As a result of acid precipitation, people may be exposed to higher levels of toxic lead, copper, aluminum, and cadmium in their drinking water. Acids strip these metals from watershed soils, like sediments, or from pipes delivering water to homes.

The owner of an Adirondack lake resort told a Congressional committee that, after his children repeatedly complained about the bad taste of his lodge's drinking water, he had the water tested. Scientists found the water to be acidic and to contain 5 times the recommended safe level for lead and 10 times this level for copper.

Acidified lakes may also induce toxic mercury contamination of aquatic life.

Economic Losses Are Staggering

Acid rain is already costing us incredible sums. Stopping the pollution at its source will also cost money. But, corrective measures will be cheaper than the sustained economic losses caused by acid rain. For 200 fishless lakes in the Adirondacks, loss of angling revenue each year is placed at $1.5 million. In the Eastern U.S., acid precipitation destroys $13 billion worth of materials yearly (according to at least one estimate). Damage to forests could reach $1.75 billion annually, and crop damage in the Ohio River basin alone could mount to $8.3 billion over the next 20 years. Health costs have been pegged at $40 million for Minnesota alone.

Several sources contend that control costs would be comparatively modest. For example, Data Resources, Inc. recently estimated that all environmental rules (with air quality programs forming only a small part) would reduce the Gross National Product by only 0.7% by 1987, would actually stimulate employment and business investments, and would increase average annual consumer prices by only 0.4% per year.

In its 1981 report to Congress, the National Commission on Air Quality pegged the total 1978 costs for air pollution control at $16.6 billion, but estimated the benefits at $21.4 to $51.2 billion.

The National Commission on Air Quality has also estimated that a 7 million ton per year (or 35%) reduction in SO_2 emissions in the Eastern U.S. would cost $2.2 billion. This translates to an average utility rate increase of only 1.8% by 1990. With free interstate trading of emission reduction credits, which spreads the costs out among more sources, a 10 million ton reduction in SO_2 emissions can be achieved at an average increase in Eastern U.S. utility rates of only 1.4% (at a total annual cost of $2.4 billion—according to a 1981 contract report by ICF, Inc.) While it is true that some Midwestern states would receive higher than average increases, (up to a maximum of about 7.5%) these same states generate most of the emissions responsible for acid rain in the East. And, even with hefty rate increases, the Midwestern states would still pay less for electricity than New England and the mid-Atlantic region.

U.S. Forest Service

Solution: Control the Pollutants that Cause Acidity

Because many of the chemical steps in the conversion of sulfur dioxide and nitrogen oxides to acid are not fully understood, industry spokespeople and the Reagan Administration have called for more research into the problem. They have also urged measures such as lake liming which is the dumping of calcium compounds in lakes to neutralize the acid. Liming is a short-lived and costly corrective measure that can only be applied to a fraction of affected lakes. It is treating the symptoms, not the illness. Moreover, it restores only lakes. Damage to soils, crops, forests, wildlife, building materials, and human health remain uncorrected.

Certainly, more research is needed and should be supported by industry and federal and state governments. Still, research alone will not stop acid rain. The goal must be to emit less SO_2 and NO_X into the air so that fewer acids form in moisture-laden atmospheres to rain down on vulnerable ecosystems.

The most cost-effective (and the only reliable) solution to the problem of acid rain is to control the offending pollutants at their source. A position statement on acid rain control, developed by the National Wildlife Federation, has been endorsed by 38 scientists active in acid rain research. Though noting the uncertainties, these researchers agree that "what is already known about the acid rain phenomenon justifies and requires immediate legislative steps to begin abating emissions of human-generated acid rain precursors."

Bernie Featherson

Support from the National Academy of Sciences

The National Academy of Sciences, the most prestigious scientific body in the U.S., has also taken the position that we must reduce emissions that lead to acid rain. In a September 1981 report, an Academy panel concluded that:

- circumstantial evidence linking power plant emissions to the production of acid rain is "overwhelming";
- slowing the damage to sensitive freshwater ecosystems requires a 50% reduction in the amount of hydrogen ions deposited, or precipitation pH (a measure of hydrogen ions) levels "no lower than 4.6 to 4.7";
- continued emissions of precursor compounds at current or higher rates "in the face of clear evidence of serious hazard to human health and to the biosphere" will be "extremely risky."

To avoid those risks, these preeminent scientists urged a "prompt tightening" of sulphur and nitrogen oxide emissions from existing as well as new fossil-fuel burning utilities and other large sources such as metal smelters and cement manufacturing plants.

Congress Addresses the Problem

Even before the release of the National Academy of Sciences's report, Congress had taken note of the growing environmental threat posed by acid rain. Several acid rain bills had already been introduced in the House and Senate. Of these, the National Wildlife Federation strongly supports the **Mitchell-Stafford** bill (S.1706) in the Senate, and its House counterpart, the **Moffett-Gregg** bill (H.R. 4829). Both bills prescribe an annual 10 million ton reduction in sulfur dioxide emissions by utilities in the 31 states east of and adjacent to the Mississippi River.

The Mitchell-Stafford bill, with some 20 cosponsors, is the leading acid rain bill in the Senate, and is supported by a number of key members of the pivotal Environment and Public works Committee. It would:

- freeze SO_2 and NO_X emissions at their Jan. 1, 1981 levels;
- set up a 31-state acid rain control region (consisting of the 31 states east of and adjacent to the Mississippi River);
- require an annual reduction of 10 million tons in SO_2 emissions in this 31-state region within 10 years;
- grant states two years to determine how SO_2 will be reduced by sources under their jurisdiction (with each state's share of the 10 million ton overall reduction obligation determined on the basis of utility SO_2 emissions in each state in excess of 1.2 pounds per million Btu's, in relation to the total such emissions in the 31-state region); and
- require the Environmental Protection Agency administrator to conduct a study of acid rain's effects in the Southwest, Great Plains and Northwest.

The **Moffett-Gregg** bill in the House has 44-plus cosponsors, and has features that differ in degree, but not in substance, from the Senate bill.

What Can You Do To Help Control Acid Rain?

Let the members of Congress who represent you know that you care about acid rain. Send letters or mailgrams to your senators and representatives, call their offices, visit them when they return home. Let them know you support legislation to abate the ravages of acid precipitation. Ask senators to cosponsor and vote for the Mitchell-Stafford bill (S.1706), and your representative to do the same for the Moffett-Gregg bill (H.R.4829). If strong acid rain controls are not reported out of committee, urge your senators and representative to support addition of such controls as Floor amendments. Also, tell your representative not to support the Dingell-Broyhill bill – being pushed by the Administration and industry. This bill makes no provision to control acid rain. It contains a number of measures which would compound the acid rain problem. It would cripple the program to clean up unhealthful air, largely repeal the program to protect clean air areas, remove the teeth from federal enforcement programs, and do nothing to control toxic air pollutants.

ACT NOW! Congress is likely to vote on these key proposals by early spring. Industry has been mounting a massive campaign in support of weakening legislation like Dingell-Broyhill. Congressional offices are being flooded with mail in support of this "dirty air" bill. It is vitally important that congressmen and senators start hearing from constituents who support a strong Clean Air Act and favor controls on acid rain. Every letter counts. Please add your voice.

Let's stop the rainbath of acid which is killing fish and wildlife and is costing our nation hundreds of millions of dollars a year in sterilized lakes and rivers, in lost recreational and tourist dollars, in potential losses of crop and forest productivity, in escalating health-care costs, and in scarred buildings and corroded cars. The time for legislative action is now!

If you'd like to participate in the National Wildlife Federation's acid rain control efforts, please fill out and return the form on the inside back cover.

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Photographs from *Stone: Properties, Durability in Man's Environment* by E. M. Winkler, Springer-Verlag, 1973

Built in 1702 at Herten Castle in Germany, this stone statue sustained only slight damage in the 200 years that passed before the photograph at left was taken. Just 60 years later, however, industrial pollution had completely eroded its features (right).